THE WARM FEBRUARY OF 1925 IN THE UNITED STATES

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[Dated March 31, 1925]

February, 1925, in continental United States was the warmest February during the last 40 odd years. It has been warmer in individual districts in other years, but considering the country as a single geographic unit no other February has averaged as much as 5.8° F. above the normal for the country as a whole. The monthly departures ranged from a minimum of 1.2° above in the Florida peninsula to 10.1° above in the region embraced by the States of Montana, Wyoming, and the western parts of South Dakota and Nebraska. Chart III of the February REVIEW shows the geographical distribution of the monthly departures.

Attempt is made in what follows to correlate this pronounced temperature abnormality with atmospheric pressure and movement of cyclones and anticyclones.[1]

One naturally looks to the pressure distribution over the eastern North Pacific and Alaska as offering a first approximation to the cause of the temperature departure.

The Northern Hemisphere twice-daily weather charts, although still far from complete, give some idea of the pressure distribution of the month. The outstanding pressure formations of the northeastern Pacific are the so-called North Pacific HIGH and the Aleutian LOW. Assuming that the average geographic position of the former in winter is longitude 140° W., latitude 35° N., and scaling from the morning Northern Hemisphere daily weather charts the daily pressures at the intersection of the two coordinates above given, I find that for December, 1924, average pressure in the center of the North Pacific HIGH was 0.06 inch below normal, for January, 1925, slightly above normal (+0.03), and that for the first half of January it was 0.33 inch higher than for the last half. The average for February determined in the same way was but 29.98 inches, or 0.22 inch below normal, therefore, pressure in the region occupied by the North Pacific HIGH was lower than usual from the middle of January to the end of February, 1925.

Statistical investigations of the relation between the pressure at Honolulu and over the Aleutians show that there is a sort of seesaw between the pressure of the two regions; that is, when pressure at Honolulu is low, pressure at the Aleutians is high, and vice versa. This relation seems, however, to be less pronounced than the similar one between the Azores and Iceland, partly because Honolulu pressures represent conditions on the extreme southwestern margin of the North Pacific HIGH, and perhaps to some extent also because the data are still somewhat scanty.

Pressure at Dutch Harbor in the Aleutians, also in interior Alaska and the Canadian Northwest in February, 1925, was also below the normal, so that we have to do with a widespread and pronounced departure of pressure below the normal.

How are we to interpret this phenomenon in terms of the weather in continental United States? Low pressure in Alaska and the Canadian Northwest is a condition favorable to the movement inland of cyclonic systems having their origin over the Pacific and, as we shall point out later, the many cyclones passing eastward along the northern border induce almost continuous southerly winds and consequently relatively high temperature. Now, if concurrently with the above the pressure over eastern United States and the western portion of the North Atlantic should be above the normal the flow of southerly winds will be intensified and the magnitude of the departure from normal will be increased.

Cyclones.—Reference to Chart II, Tracks of Centers of Cyclones, in the February, 1925, REVIEW, will show that while a relatively large number of cyclones has been plotted as originating over the Pacific, but a single one succeeded in crossing the continent.

The number of secondary cyclones that developed in February over the eastern Rocky Mountain slopes was considerably greater than usual, a circumstance probably closely related to the pressure distribution over the northeastern Pacific. On the whole, both primary and secondary cyclones of the month lacked in intensity and naturally strong pressure gradients were absent.

Anticyclones.—Tracks of anticyclones for February, 1915, are shown in the REVIEW for that month, Chart I. A fairly large proportion of these came in from the Pacific evidently being offshoots from the North Pacific HIGH and consequently were not associated with an indraught of cold air. The few anticyclones that came down from the Canadian Northwest likewise were not associated with the low temperatures characteristic of midwinter; thus we conclude that the cause of the exceptionally warm weather of February is explainable only when we clearly understand the reason for the weak pressure gradients of the month for northerly winds. If, instead of relatively high temperature in Alaska, the temperature had been low, a greater flow of polar air to the southward might have been expected.

This is equivalent to saying that in the final analysis the cause of pronounced abnormalities in the weather must be referred to the day-to-day movement of cyclones and anticyclones both in time and space. The latter will be considered more in detail in the concluding part of this paper.

It is only within the last year or so that weather charts for the Northern Hemisphere have become available, even in skeleton form. The network of vessel-reporting stations is as yet far too open-meshed to afford an accurate picture of the pressure distribution over the vast area of the Pacific, moreover, ships will continue to ply the oceans in the most direct sailing routes between the West and the East and vice versa. Thus reports from the remote and less traveled routes can hardly be expected, although reports from these regions are just as necessary to the meteorologist as those along great circle sailing routes.

At present weather reports are lacking for the region near and along the Arctic Circle from about 60° to 160° E., or a little more than one-quarter of the circumference of the globe. Weather reports from the remainder of high latitude areas are sufficient to picture in a general way that in winter a chain of cyclonic storms encircles at least three-fourths of the globe between the Arctic Circle as the northern limit and the belt of high pressure which spans the globe about 35° N. latitude.

It is to the latitudinal range in the path of cyclones and anticyclones that the variations in the weather of the greater part of the Northern Hemisphere are probably due. I say "probably" because no one has as yet shown that any other single element or combination of elements, whether of terrestrial or cosmical origin, has an influence as pronounced as that mentioned.

[1] These terms "cyclone and anticyclone" are synonymous with the familiar words "low and high" of the daily weather chart and are so used throughout this paper.

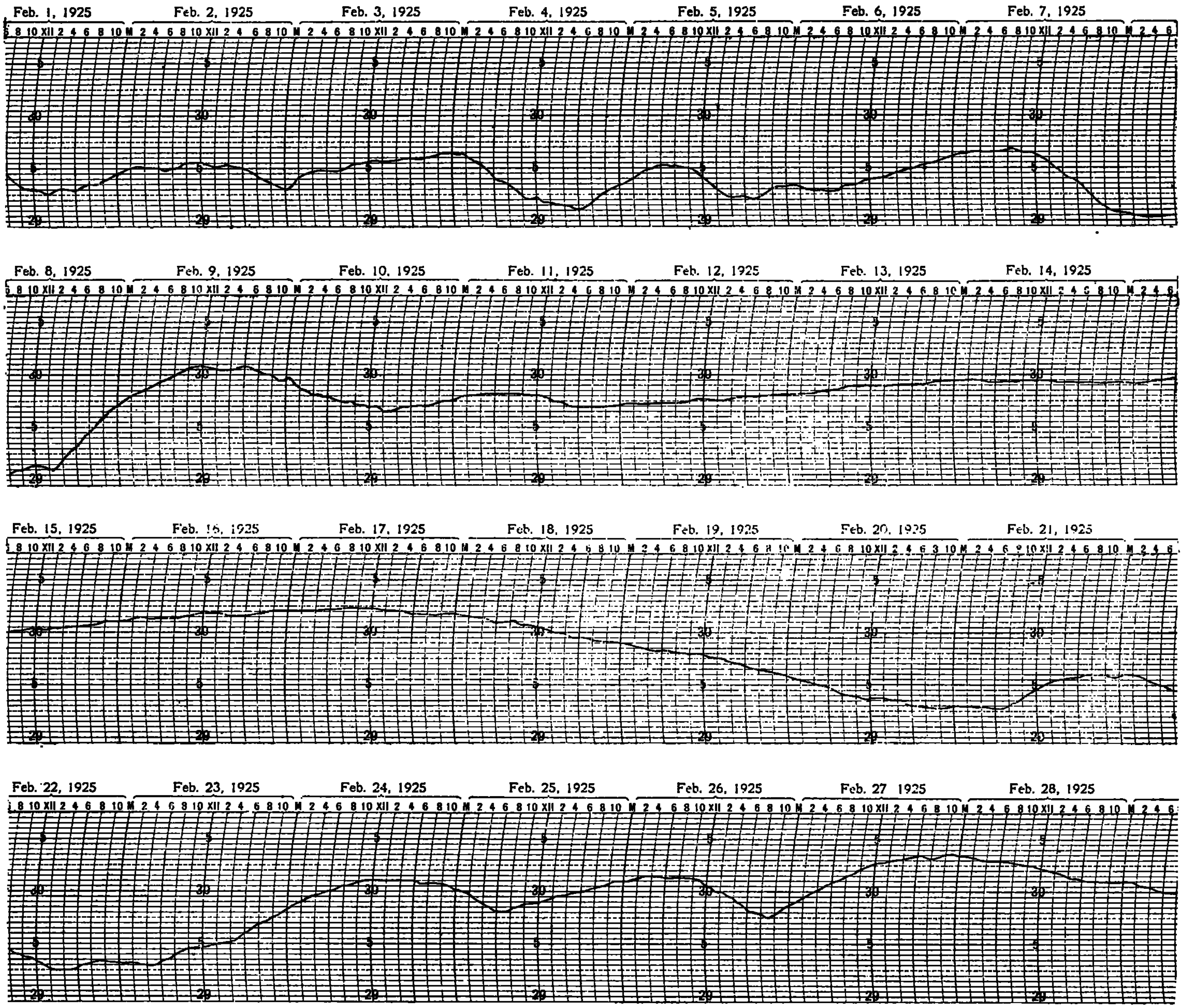

FIG. 1.—Barograms, Tatoosh Island, February, 1925

Whether in the years to come it will be possible to accurately delimit the movement of cyclones and anticyclones in latitude is still a debatable question.

Many references have appeared in the literature of long-range weather forecasting as to the control on the weather exerted by the so-called "centers of action," one of which, the North Pacific HIGH, comes within the purview of our inquiry. As previously stated, average pressure in that high during the last half of January and throughout February, 1925, was significantly below normal. Assuming that the published normal of 30.20 inches for the region in question is correct, a comparison of the daily February pressures with the normal shows that during February there were but 2 days with normal or above normal pressure, and, of course, 26 days with pressure below normal. The pressure in this region sank as low as 29.60 inches on the 9th–10th, when a cyclone of moderate intensity was centered in longitude 135° W., latitude 35° N. There was therefore a complete reversal of the normal pressure distribution for this particular part of the ocean.

What effect, if any, did this reversal have upon the weather of continental United States? The only direct influence so far as can be seen is the fact that the cyclone above mentioned greatly diminished in intensity, passed inland over California on the 11th, pursued a somewhat devious course, and disappeared over the Southern Plateau on the 13th.

On the dates of the reversal before mentioned the North Pacific HIGH was divided into two portions, an eastern one lying over the western United States and a western one over the ocean in longitude 160° to 170° W. As soon as the cyclone had passed over the continent pressure conditions over the ocean reverted to normal; hence the effect on the weather of the United States was only temporary.

It is difficult to consider the day-to-day fluctuations in pressure in the aggregate for a month or longer; I have therefore drawn and present the barograph curves of Tatoosh Island—a prominent oceanic outlook station off the extreme northwest tip of the State of Washington—for the month of February, 1925. (See Fig. 1.)

The month has been divided into three portions, first, from February 1 to 10, when pressure rose and fell in a sort of cycle of one to two days in length, the hollows in the curves representing times when cyclonic storms approached the coast and the crests days when anticyclones were experienced.

The second period, viz, from the 10th to the 20th, was characterized by a slow but uniform increase in pressure to a crest about the 16th or 17th, when a more rapid fall to another cyclonic or storm period set in on the 20th and continued until the close of the month.

A verbal statement of the weather experienced during these three periods would not only be tedious but would also fail to convey an accurate image of what occurred; hence several series of weather maps will be presented to indicate the pressure formations which gave character to the weather experienced during the periods.

Northern Hemisphere weather charts.—The first series embraces the morning charts for February 1–4. To avoid congestion, the isobars on these charts for pressures below 30 inches have been drawn for intervals of three-tenths of an inch instead of one-tenth, as usual. In this and other series the peculiar trend of the isobars of a Pacific cyclone when approaching and passing onto the continent is clearly shown.

There is a resemblance between the charts here presented and that one drawn by Guldberg and Mohn on theoretical grounds in their well-known discussion of the movements of the atmosphere when a cyclone lies partly over land and partly over water.[2]

First indications of development of cyclones over land.—When the front of a Pacific cyclone of winter crosses the coast line, the isobars are systematically bent or bowed toward the southeast, never or rarely ever toward the northeast or north.

There is reason for thinking that the inflection toward the southeast is dependent on air column temperatures on the leeward side of mountain ranges that trend north-south over western North America. Since cyclones very frequently develop in the rear of eastward moving anticyclones a region of southerly and hence warm winds and also since, on occasion, high air temperatures (relatively) may result from compression in the descent of winds to the lower levels on the eastern or lee side of the mountains, that side must be a favorable location for the development of secondary disturbances. Eastern Colorado is such a location.

In a large number of cases a cyclone over the continent does not immediately develop as an oceanic cyclone approaches the coast, but in the ensuing 24 to 36 hours a low pressure area without well-developed cyclonic wind circulation generally appears either over the Plateau region or directly east of the main range of the Rocky Mountains; thus, reverting to Figure 2 and the chart for February 1, it will be noted that the isobar of 30 inches curves sharply to the southeast over British Columbia and northern Montana. This inflection becomes more pronounced on the succeeding charts of the 2d and 3d and finally on the chart for the 4th a separate cyclone is shown, while the original remains practically in its position over the Aleutians.

[2] Guldberg and Mohn in Mechanics of the Atmosphere, C. Abbe's 3d collection of translations, p. 233.

An examination of the April, 1925, Northern Hemisphere weather charts leads to the belief that the development of cyclones in the rear of an eastward moving anticyclone is more common than was at first thought. Very briefly described the situation in the beginning is as follows: The North Pacific anticyclone is close inshore and the companion continental anticyclone is likewise near the western shore line of the continent. Offshoots from these anticyclones are given off from time to time and move in a southeasterly direction; as soon as they gain distance to the eastward a trough or lane of low pressure is established between the two anticyclones. This trough serves as a channel along which offshoots from the Aleutian LOW advance over the continent. The channel may be closed at any place between latitude 40 and 60 N. by rising pressure which seems to advance from both the interior and the oceanic anticyclonic areas. Sometimes, but not often, the two anticyclones merge and remain merged for several days. At such times very cold weather prevails over the continent.

The closure rarely endures more than a day or so. The opening of the channel is brought about by falling pressure that is associated with cyclones which advance eastward over the Aleutians or the Gulf of Alaska, in connection with the east-southeast drift of the interior anticyclone.

Attention is directed to the southward looping of the isobar of 29.7 inches surrounding the Aleutian LOW of the 4th and to the fact that this looping may be taken as an indication that a secondary cyclone will be given off over the Canadian Northwest, as actually occurred on the 5th. Thus two secondaries one on the 4th, one on the 5th and yet a third was given off or developed over Montana on the p. m. of the 6th.

An intense North Pacific cyclone.—The second series of charts begins with the p. m. chart of the 7th and this is followed by the a. m. chart of the 8th, 9th, and 10th, respectively. This series shows something of the wind circulation in an intense North Pacific cyclone as it approaches the shore of the continent. Note for example the winds of hurricane force blowing in the rear half of the storm figured in the charts p. m. 7th and a. m. 8th. On the land side the winds were gentle to fresh; in the valleys and sheltered positions the velocity on the morning of the 8th was less than 10 m. p. h. and naturally the direction in these cases was controlled by local topography rather than by the barometric gradient.

The a. m. chart of the 8th presents an unusually interesting situation. One can not help wondering what becomes of the winds of hurricane force over the ocean in the left half of the cyclone. Evidently they do not curve around the center as in a true tropical cyclone since the maximum wind velocity for the date in question was but 64 m. p. h. at an exposed point on the Washington coast.

It may be that the unbalanced system of forces in the vortex operates to destroy it, in any event the examination of a number of cases leads to the conclusion that the intensity of winter cyclones of the northeast Pacific diminishes rapidly as the cyclones impinge upon the coast.

Prof. T. Terada of the Imperial Univeristy of Tokyo has shown statistically[3] that the cyclones of the Far East have a tendency to pass over land in summer, while they move over water, avoiding land in winter.

[3] Quoted by T. Kobayasi in Quarterly Jour. Loyal Met. Soc. 48: 169.

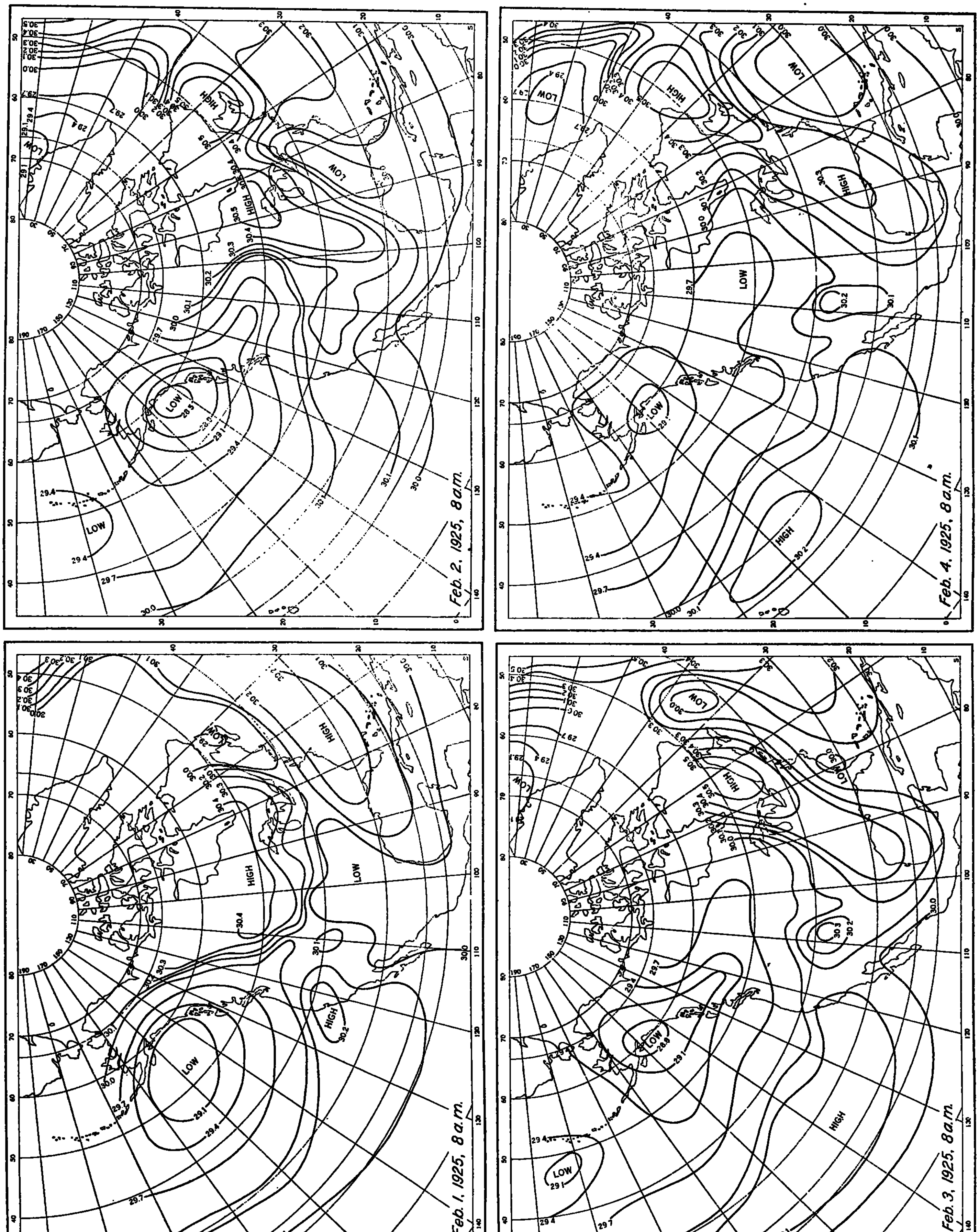

FIG. 2.—Pressure distribution, eastern North Pacific and North America, February 1-4, 1925

The charts of the 9th and 10th present very interesting transformations. The great cyclone of the 8th, or what was left of it, was centered about longitude 138° W., latitude 42° N., where it had apparently severed the North Pacific HIGH into two parts as shown on the above-named charts.

The period February 10–20.—Reference to Figure 1 will show that after a rise in pressure at Tatoosh Island on the 9th, pressure then fell slightly as the cyclone mentioned in the preceding paragraph passed inland; it then rose rather slowly but uniformly to a crest on the 16th–17th, then fell to the minimum of the 20th. During this time cyclones did not come in from the Pacific; however, three, all of continental origin, gave to the weather east of the 100th meridian the character it possessed. The first of the three developed over the Province of Alberta, directly in the rear of an eastward moving anticyclone. The remaining two developed over eastern Colorado, moved thence to Oklahoma, recurved to the northeast, and eventually passed off to sea over the Atlantic. During this time three weak anticyclones came from Canada and while temperature was lowered for a short time it almost immediately regained its former high level.

The final period, February 20–28.—This period was characterized by rather frequent but not pronounced storm movement. As early as the 19th the isobar of 29.90 inches of a great oceanic cyclone had extended southeastward over the continent almost to the Mississippi River, thus forming a great loop or tongue of low pressure without pronounced cyclonic circulation over the western third of the country. Twenty-four hours later this low pressure had spread eastward so that it extended from the lower Ohio Valley to the Gulf of Alaska and this region of low pressure was flanked on the northeast and southwest by regions of higher pressure.

The Northern Hemisphere charts, p. m. 23d to a. m. 26th, not including those of the 26th, are reproduced as Figure 4.

These charts illustrate the transformations by which a fully-developed cyclone is at times formed within a great area of low pressure partly over land and partly over water.

The chart, p. m. 23d, shows a series of four cyclones in tandem, so to speak, the eastern one being centered over Atlantic Coast States. This cyclone is separated from those to the westward by a shallow ridge of higher pressure that extends from the Gulf of Mexico northward to the Lake region, where pressure is slightly below 30 inches. Ordinarily the temperature in the rear of a winter cyclone falls considerably, but in this case perhaps by reason of the close approach of a second cyclone with its system of southerly winds on the eastern margin, marked changes to lower temperature did not occur.

The p. m. chart of the 23d shows the presence of a pressure formation known to meteorologists as a "saddle"—a region of nearly uniform pressure between two adjoining HIGHS. Such a formation in this instance indicated that the eastern cyclone, or LOW, would be cut off from its connection with the oceanic low by way of the "saddle." Subsequent charts show that this was accomplished and thus an independent cyclone was set in motion.

This cyclone greatly increased in intensity as it passed down the St. Lawrence Valley. On the morning of the 27th central pressure in it had fallen to 28.95 inches at the mouth of the St. Lawrence and the gradient for northerly winds in its rear on that and the following day was much stronger than on any previous day of the month. Thus it is apparent that in the final analysie the degree of cold experienced in the several parts of ths country is conditioned very largely upon the depths to which pressure at the center of cyclonic systems falls, which in turn determines the barometric gradients and the flow of polar air equatorward.

The concluding chart of this series, February 26 (a. m.), shows the beginning of a fresh intrusion of a Pacific cyclone; it also shows the isobars of the cyclone that was centered over the mouth of the St. Lawrence that was considered in the preceding paragraph.

III. CORRELATION BETWEEN PRESSURES IN DISTANT REGIONS

Sir Gilbert Walker in his studies of world weather relations has determined and published correlation coefficients [4] between the so-called "centers of action." Among these are Honolulu, as representative of the North Pacific HIGH and a combination of Alaskan stations under the term "Alaska." Pressures from both of these points may have an important bearing on the weather of the United States, although the precise nature of the bearing has not yet been worked out. I have therefore summarized in the following table the most significant of the correlation coefficients between Honolulu pressures for the months December to February and June to August with the pressures of more or less remote regions both for contemporary pressures and for the pressure at the distant "center of action" 6 months previous. Chief interest therefore centers in the two columns headed "2 quarters before."

It is quite evident that the only significant coefficients for the 6 months previous with Honolulu are those for Port Darwin, Australia, and possibly Mauritius of plus 0.46 and 0.30, respectively. For the summer months, June to August, there is a positive correlation of 0.45 with Samoa and 0.73 for contemporary pressures. In winter, however, this correlation with Samoa is so small as to be insignificant. In this connection the point cannot be too strongly emphasized that the true importance of relations such as these is shown, not by the correlation coefficients and their probable errors alone, but by the *squares* of the coefficients. Thus for the Port Darwin-Honolulu pressure, .21 represents the true measure of contingency between them; for Mauritius-Honolulu this measure is but .09.

TABLE 1.—*Correlation coefficients, Honolulu pressure, and pressure at distant "centers of action"*

Pressure at—	December to February			June to August		
	2 quarters before	Contemporary	2 quarters after	2 quarters before	Contemporary	2 quarters after
Port Darwin	+0.46	+0.39	+0.11	−0.33	−0.67	−0.64
Mauritius	+.30	−.25	−.18	−.31	−.22	−.10
Central Siberia	−.20	−.29	−.39	+.07	−.16	−.09
Alaska	−.15	−.71	−.03	−.12	−.28	+.23
Southeast Australia	+.28	+.33	+.21	−.25	−.28	−.54
Azores	+.15	+.15	+.21	+.07	+.20	−.09
Charleston	+.09	−.20	+.21	+.10	−.08	+.30
South Orkneys	+.01	+.37	−.46	+.16	−.07	−.01
Samoa	+.08	+.19	+.03	+.45	+.73	+.50
South America	+.12	+.07	+.19	−.01	+.52	−.05

Finally, I conclude that the explanation of the warm weather experienced in the last part of January and during February, 1925, must be referred to the presence of an oceanic cyclone over the Gulf of Alaska which influenced the weather on the continent in two distinct ways: (1) It provided suitable atmospheric conditions whereby a number of rather ill-defined cyclonic systems were detached from the primary oceanic cyclone and passed

[4] Walker, Gilbert T., Memoirs of the Indian Meteorological Department, Vol. XXIV, Part IV, pp. 88–103.

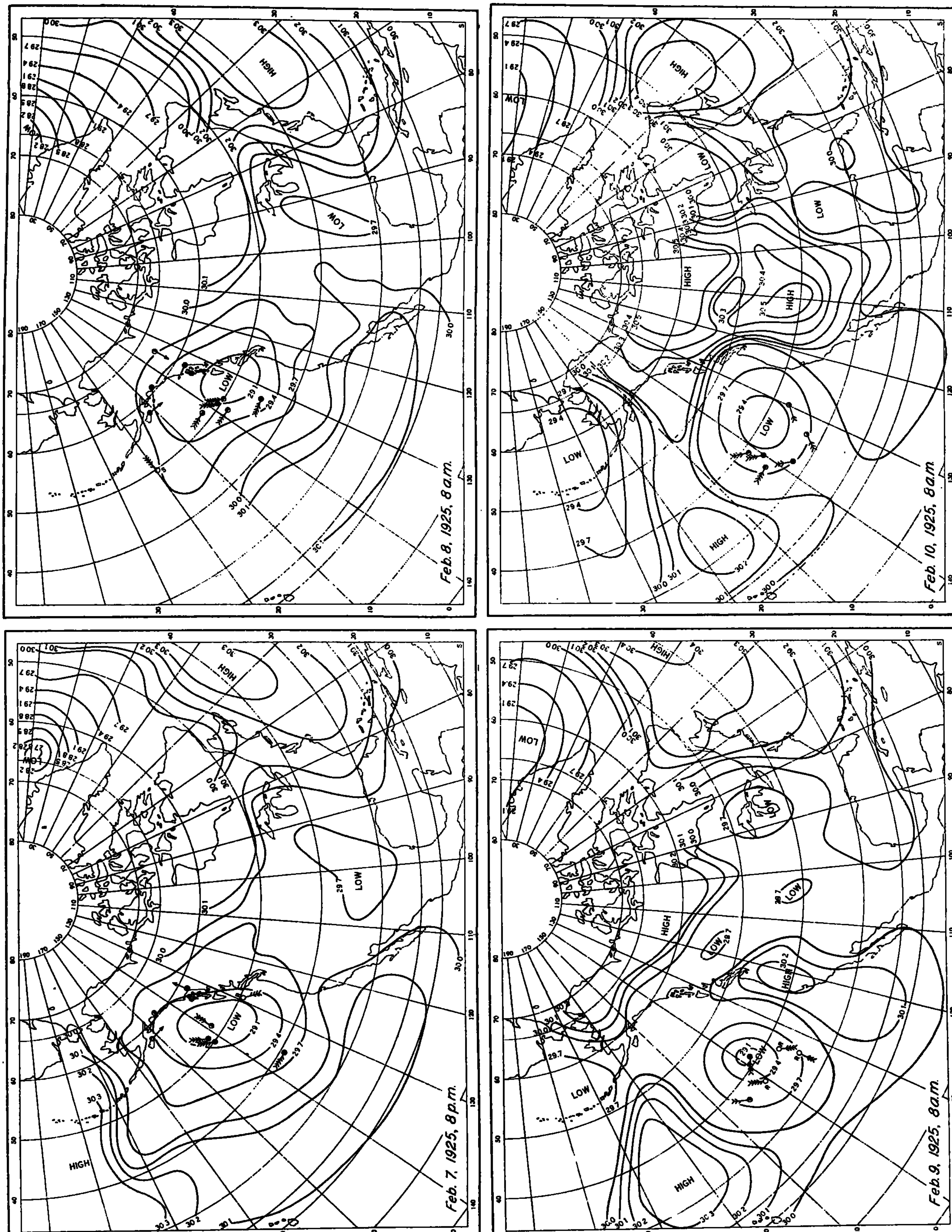

FIG. 3.—Pressure distribution, eastern North Pacific and North America, February 7-10, 1925

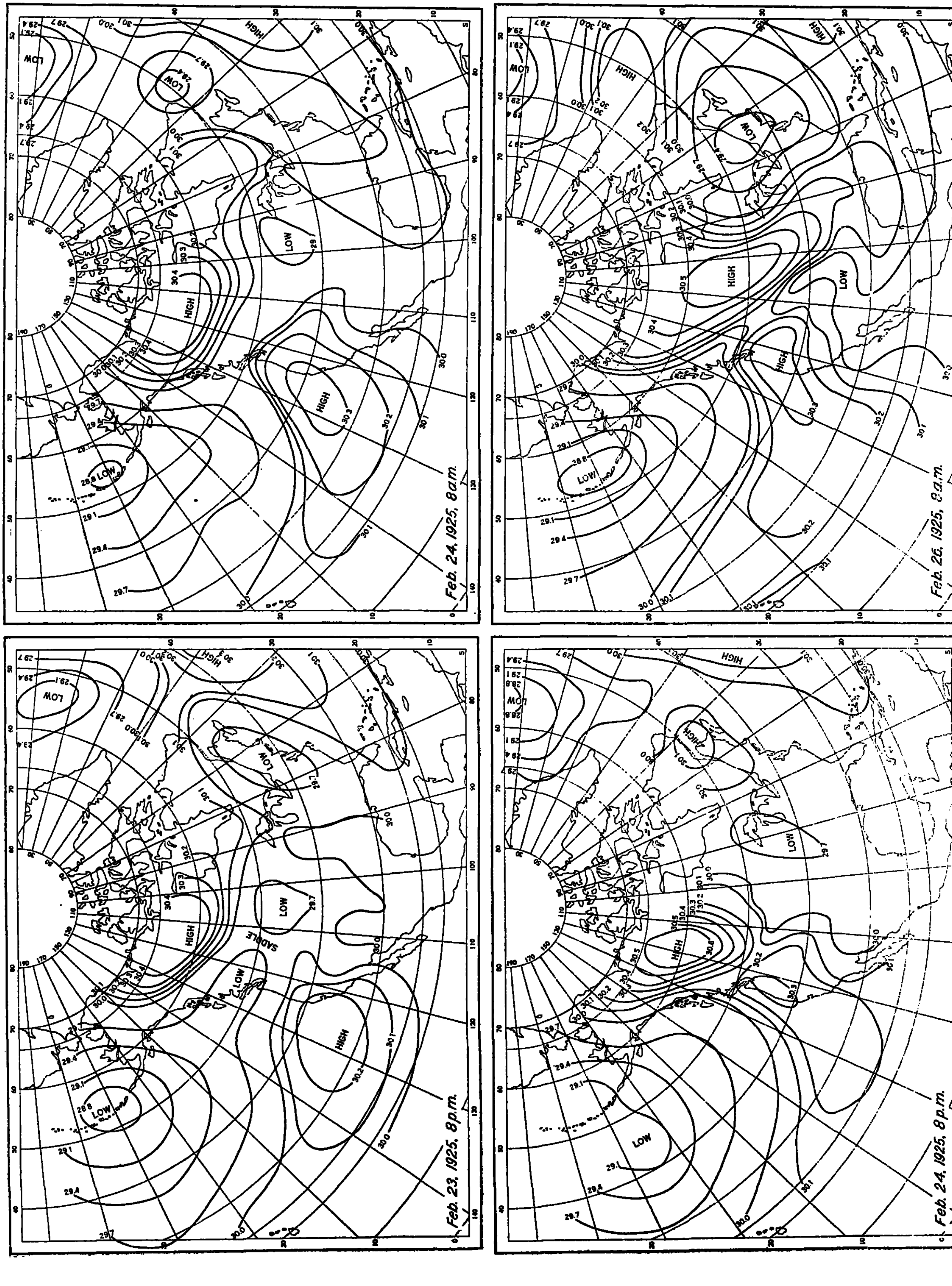

FIG. 4.—Pressure distribution, eastern North Pacific and North America, February 23–24, and 26, 1925.

along the northern boundary toward the Atlantic, thus inducing on their fronts an unusual frequency of southerly winds; (2) the presence of this oceanic cyclone off the coast of Alaska and the British Northwest operated to maintain relatively high temperatures in those regions, so that when the barometric gradients were favorable to a flow of polar air equatorward the gravitational pull in that direction was less than usual because of the warmth of the polar air. As a result, no pronounced cold waves swept southward.

The object of this and similar studies [5] is to evaluate the influence of the North Pacific pressure distribution upon the weather of the North American Continent as a factor in the daily forecasts, also to discover to what, if any, extent a foreknowledge of that distribution may be helpful in seasonal forecasting, assuming, of course, that it may be possible to forecast the pressure distribution over the Pacific, a possibility not yet demonstrated.

It is highly improbable that useful generalizations as to the sequence of weather in North America can be drawn from the consideration of the pressure distribution over the northeast Pacific for a single winter and none will be attempted.

The work thus far is not entirely fruitless since it confirms in a general way the conclusions recently set forth by Sir Frederick Stupart.[6]

There is a growing belief on the part of meteorologists that the cause of unusual seasonal variations is in some way related to the conditions that prevail in Arctic and Antarctic regions.

The North American Continent is unfavorably situated with respect to the Arctic as compared with European countries. Instead of a warm oceanic current that makes its way far into polar seas, as in Europe, North America is hedged in by a frigid polar sea and a great interior continental area devoid of meteorological outposts whence useful information as to weather conditions might come. Progress in ameliorating this need is being made, thanks to the Canadian Weather Service. Another hindrance to weather prevision beyond 24–36 hours is a lack of knowledge of free-air conditions along the western coast on the approach of an oceanic cyclone and back of all this lies the most difficult problem of anticipating the pressure distribution over the vast extent of water surface which separates the North American Continent from Asia and the islands of the Far East.

[5] Henry, A. J., Seasonal forecasting of precipitation, Pacific Coast States, MONTHLY WEATHER REVIEW 49: 213-219. Pressure over northeastern Pacific and weather in United States December, 1924, and January, 1925, 53: 5-10.

[6] Stupart, F., The variableness of Canadian winters. Presented before the British Association for the Advancement of Science at its Toronto meeting of August, 1924, abstracted in this Rev. 52: 351.

TORNADOES OF THE UNITED STATES, 1916-1923[1]

By HERBERT C. HUNTER

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With the year 1916 the Weather Bureau resumed the systematic collection for the whole country of tornado statistics which had ceased at the end of 1897. The important tornadoes during this 18-year interval had, however, been described, chiefly in the MONTHLY WEATHER REVIEW, likewise some minor ones of special interest; while in a few States there was sustained effort to list every storm of great violence, tornado or not.

The results for eight years, to the end of 1923, have been compiled and are now shown in Table 1. The study covers the distribution by States and the losses of both life and property. The details were printed regularly, year by year, in the Report of the Chief of the Weather Bureau, with a chart for each year to illustrate the occurrence.

The following new items, coming to notice since the respective reports went to press, have been included in the statistics:

Missouri.—One death from the tornado of June 1, 1917, in Jackson County.

New England.—The violent storm in Massachusetts, Norfolk, and Plymouth Counties, about 4 p. m., August 31, 1920, in view of further information, is considered a tornado. There were no fatalities, but the property loss was about $200,000.

North Dakota.—A storm, not known previously, is reported as a tornado, in Traill County, north of Mayville, August, 1919, about the 25th. The damage was unimportant and almost undoubtedly no lives were lost.

In a few instances the total number of deaths or total damage from a number of tornadoes within a single State during a month or other short period of time was printed, but the exact number of those tornadoes that did involve loss of life or property loss to a certain amount was not printed and is not now known. In order to show as well as possible how many tornadoes caused deaths or heavy damage it has been thought best to allot the totals in a somewhat unequal way, about as is most frequently found to happen with similar groups of tornadoes when all the details are still accessible. The cases where such allotment enters, rather than the complete details, are so few that the greatest possible error from this cause in the figures of Table 1 is of little consequence.

Two columns are introduced in Table 1 which relate not to the storms classed as tornadoes, but to severe winds that seem not to have been tornadoes, including hurricanes of tropical origin, thunderstorm squalls, and other violent winds which can cause loss of property or of life. The division in these columns of the deaths and property damage reported from the Maryland-Delaware section and the New England section between the individual States that compose those sections can not now be made exactly (as is entirely possible for the tornadoes), but is given approximately. For several States, as a footnote indicates, the estimates of damage for these miscellaneous winds are known or believed to be decidedly incomplete.

In securing this material and compiling these reports, from 1916 onward, the Climatological Service has been the principal means. This service assigns a certain area, almost always an exact State, to each of 45 section directors. The tornado information, like much other material, is assembled and passed upon first by these directors, then the compiling is finished at Washington. By direction of the Chief of the Weather Bureau the work was started and has always been supervised by P. C. Day, head of the Climatological Division; most of the actual compiling at Washington was handled for 1916 by Joseph B. Kincer, but for the subsequent years by the writer. Much assistance has been found in the preliminary table of severe storms, including several

[1] Presented in part to the American Meteorological Society at Washington, D. C., Jan. 2, 1925.